# APPENDIX A
# SEDIMENT CONTRIBUTION FROM HILLSLOPE EROSION

**Introduction**

Upland sediment loading due to hillslope erosion was modeled using the Universal Soil Loss Equation (USLE), and sediment delivery to the stream was predicted using a sediment delivery ratio. This model provided an assessment of existing sediment loading from upland sources and an assessment of potential sediment loading through the application of Best Management Practices (BMPs). For this evaluation the primary BMP evaluated includes the modification in upland management practices. When reviewing the results of the upland sediment load model it is important to note that a significant portion of the remaining sediment loads after BMPs in areas with grazing and/or silvicultural land-uses is also a component of the “natural upland load”. However, the assessment methodology didn’t differentiate between sediment loads with all reasonable BMPs and “natural” loads.

A list of land cover classifications used in the USLE model is presented in **Table A-1**, along with a description of which land-use was associated with each cover type for the purposes of sediment source assessment and load allocations.

**Table A-1. Land Cover Classifications for the USLE Model.**

| Land Cover Classifications | Land-use / Sediment Source |
|---|---|
| Bare Rock/Sand/Clay | Natural Source |
| Deciduous Forest | Natural Source |
| Evergreen Forest | Natural Source |
| Mixed Forest | Natural Source |
| Woody Wetlands | Natural Source |
| Logging | Silviculture |
| Grasslands/Herbaceous | Agriculture |
| Shrubland | Agriculture |
| Pasture/Hay | Agriculture |
| Small Grains | Agriculture |
| Fire | Fire |

**Universal Soil Loss Equation (USLE)**

The general form of the USLE has been widely used for erosion prediction in the U.S. and is presented in the National Engineering Handbook (1983) as:

$$(1)\ A = RK(LS)CP \text{ (in tons acre}^{-1}\text{ year}^{-1}\text{)}$$

where soil loss (A) is a function of the rainfall erosivity index (R), soil erodibility factor (K), overland flow slope and length (LS), crop management factor (C), and conservation practice factor (P) (Wischmeier and Smith 1978, Renard et al. 1991). The USLE estimates average soil loss from sheet and rill erosion but does not estimate soil loss from gully erosion. USLE was selected for the upper Big Hole watershed due to its relative simplicity, ease in parameterization, and the fact that it has been integrated into a number of other erosion prediction models. These include: (1) the Agricultural Nonpoint Source Model (AGNPS), (2) Areal Nonpoint Source

Watershed Environment Response Simulation Model (ANSWERS), (3) Erosion Productivity Impact Calculator (EPIC), (4) Generalized Watershed Loading Functions (GWLF), and (5) the Soil Water Assessment Tool (SWAT) (Doe, 1999). A detailed description of the general USLE model parameters is presented below.

The R-factor is an index that characterizes the effect of raindrop impact and rate of runoff associated with a rainstorm. It is a summation of the individual storm products of the kinetic energy in rainfall (hundreds of ft-tons acre-1 year-1) and the maximum 30-minute rainfall intensity (inches hour-1). The total kinetic energy of a storm is obtained by multiplying the kinetic energy per inch of rainfall by the depth of rainfall during each intensity period.

The K-factor or soil erodibility factor indicates the susceptibility of soil to resist erosion. It is derived by measurement of soil particle size (texture), percent organic matter, structure, and permeability. It is a measure of the average soil loss (tons acre-1 hundreds of ft-tons-1 per acre of rainfall intensity) from a particular soil in continuous fallow. The K-factor is based on experimental data from the standard SCS erosion plot that is 72.6 ft long with uniform slope of 9 percent.

The LS-factor is a function of the slope and overland flow length of the eroding slope or cell. For the purpose of computing the LS-value, slope is defined as the average land surface gradient. The flow length refers to the distance between where overland flow originates and runoff reaches a defined channel or depositional zone. According to McCuen, (1998), flow lengths are seldom greater than 400 or shorter than 20 feet.

The C-factor or crop management factor is the ratio of the soil eroded from a specific type of cover to that from a clean-tilled fallow under identical slope and rainfall. It integrates a number of factors that effect erosion including vegetative cover, plant litter, soil surface, and land management. The original C-factor of the USLE was experimentally determined for agricultural crops and has since been modified to include rangeland and forested cover. It is now referred to as the vegetation management factor (VM) for non-agricultural settings (Brooks, 1997).

Three different kinds of effects are considered in determination of the VM-factor. These include: (1) canopy cover effects, (2) effects of low-growing vegetal cover, mulch, and litter, and (3) rooting structure. A set of metrics has been published by the Soil Conservation Service (SCS) for estimation of the VM-factors for grazed and undisturbed woodlands, permanent pasture, rangeland, and idle land. Although these are quite helpful for the upper Big Hole watershed, Brooks (1997) cautions that more work has been carried out in determining the agriculturally based C-factors than rangeland/forest VM-factors. Because of this, the results of the interpretation should be used with discretion.

The P-factor (conservation practice factor) is a function of the interaction of the supporting land management practice and slope. It incorporates the use of erosion control practices such as strip-cropping, terracing, and contouring, and is applicable only to agricultural lands. Values of the P-factor compare straight-row (up-slope down-slope) farming practices with that of certain agriculturally-based conservation practices.

**Modeling Approach**
Sediment delivery from hillslope erosion was estimated using a Universal Soil Loss Equation (USLE) based model to predict soil loss, along with a sediment delivery ratio, (SDR) to predict sediment delivered to the stream. This USLE based model is implemented as a watershed scale, grid format, GIS model using ArcView v 9.0 GIS software.

Desired results from the modeling effort include the following: (1) annual sediment load from each of the water quality limited segments on the state's 303(d) List, and (4) the mean annual source distribution from each land category type. Based on these considerations, a GIS-modeling approach (USLE 3-D) was formulated to facilitate database development and manipulation, provide spatially explicit output, and supply output display for the modeling effort.

**Modeling Scenarios**
Two upland management scenarios were proposed as part of the Upper Big Hole River modeling project. They include: (1) an existing condition scenario that considers the current land use cover and management practices in the watershed and (2) an improved grazing and cover management scenario.

Erosion was differentiated into two source categories for each scenario: (1) natural erosion that occurs on the time scale of geologic processes and (2) anthropogenic erosion that is accelerated by human-caused activity. A similar classification is presented as part of the National Engineering Handbook Chapter 3 - Sedimentation (USDA, 1983). Differentiation is necessary for TMDL planning.

**Data Sources**
The USLE-3D model was parameterized using a number of published data sources. These include information from: (1) USGS, (2) Spatial Climate Analysis Service (SCAS), and (3) Soil Conservation Service (SCS). Additionally, local information regarding specific land use management and cropping practices was acquired from the Montana Agricultural Extension Service and the Natural Resource Conservation Service (NRCS). Specific GIS coverages used in the modeling effort included the following:

<u>R – Rainfall factor</u>. Grid data of this factor was obtained from the NRCS, and is based on Parameter-elevation Regressions on Independent Slopes Model (PRISM) precipitation data. PRISM precipitation data is derived from weather station precipitation records, interpolated to a gridded landscape coverage by a method (developed by the Spatial Climate Analysis Service of Oregon State University) which accounts for the effects of elevation on precipitation patterns.

<u>K – Soil erodibility factor</u>. Polygon data of this factor was obtained from the NRCS General Soil Map (STATSGO) database. The USLE K factor is a standard component of the STATSGO soil survey. STATSGO soils polygon data were summarized and interpolated to grid format for this analysis.

<u>LS – Slope length and slope factors</u>. These factors were derived from 30m USGS digital elevation model (DEM) grid data, interpolated to a 10m pixel.

C – Cropping factor. This factor was estimated using the National Land Cover Dataset (NLCD), using C-factor interpretations provided by the NRCS and refined by Montana DEQ using SCS C-factor tables (Brooks et al. 1997). C-factors are intended to be conservatively representative of conditions in the Big Hole valley.

P – Management practices factor. This factor was set to 1, as consultation with the NRCS State Agronomist suggests that this value is the most appropriate representation of current management practices in the Big Hole valley (i.e. no use of contour plowing, terracing, etc).

**Method**

An appropriate grid for each factors' values was created, giving full and appropriate consideration to proper stream network delineation, grid cell resolution, etc. A computer model was built using ArcView Model Builder to derive the five factors from model inputs, multiply the five factors and arrive at a predicted sediment production for each grid cell. The model also derived a sediment delivery ratio for each cell, and reduced the predicted sediment production by that factor to estimate sediment delivered to the stream network.

Specific parameterization of the USLE factors was performed as follows:

Upper Big Hole DEM

The digital elevation model (DEM) for the upper Big Hole watershed was the foundation for developing the LS factor, for defining the extent of the bounds of the analysis area (the upper Big Hole watershed), and for delineating the area within the outer bounds of the analysis for which the USLE model is not valid (i.e. the concentrated flow channels of the stream network). The USGS 30m DEM (level 2) for the upper Big Hole was used for these analyses. First the DEM was interpolated to a 10m analytic grid cell to render the delineated stream network more representative of the actual size of upper Big Hole watershed streams and to minimize resolution dependent stream network anomalies. The resulting interpolated 10m was then subjected to standard hydrologic preprocessing, including the filling of sinks to create a positive drainage condition for all areas of the watershed.

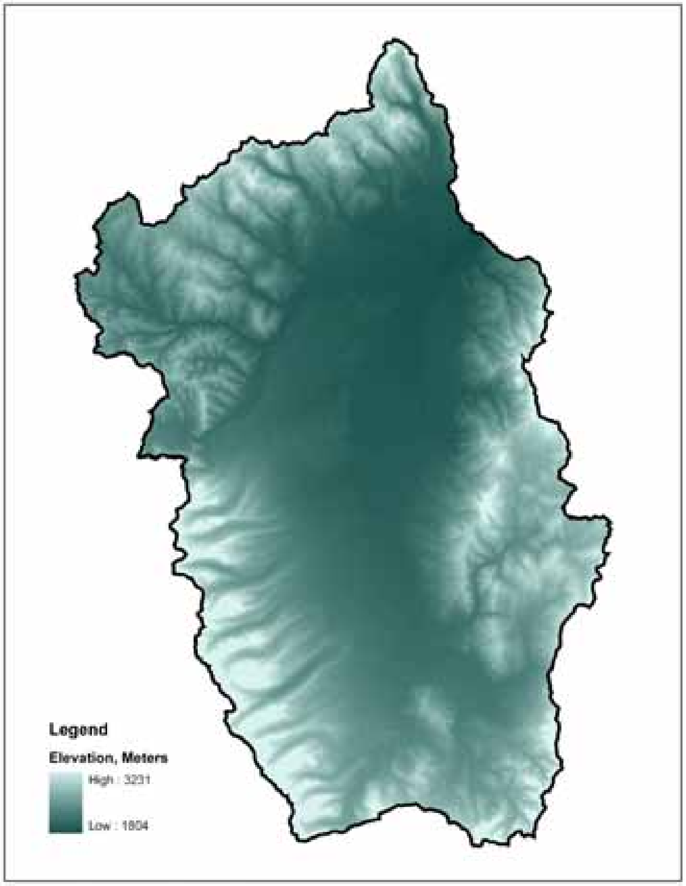



**Figure A-1. Digital Elevation Model (DEM) of the upper Big Hole watershed, prepared for hydrologic analysis.**

<u>R-Factor</u>

The rainfall and runoff factor grid was prepared by the Spatial Climate Analysis Service of Oregon State University, at 4 km grid cell resolution. For the purposes of this analysis, the SCAS R-factor grid was reprojected to Montana State Plane Coordinates (NAD83, meters), resampled to a 10m analytic cell size and clipped to the extent of the upper Big Hole watershed, to match the project's standard grid definition.

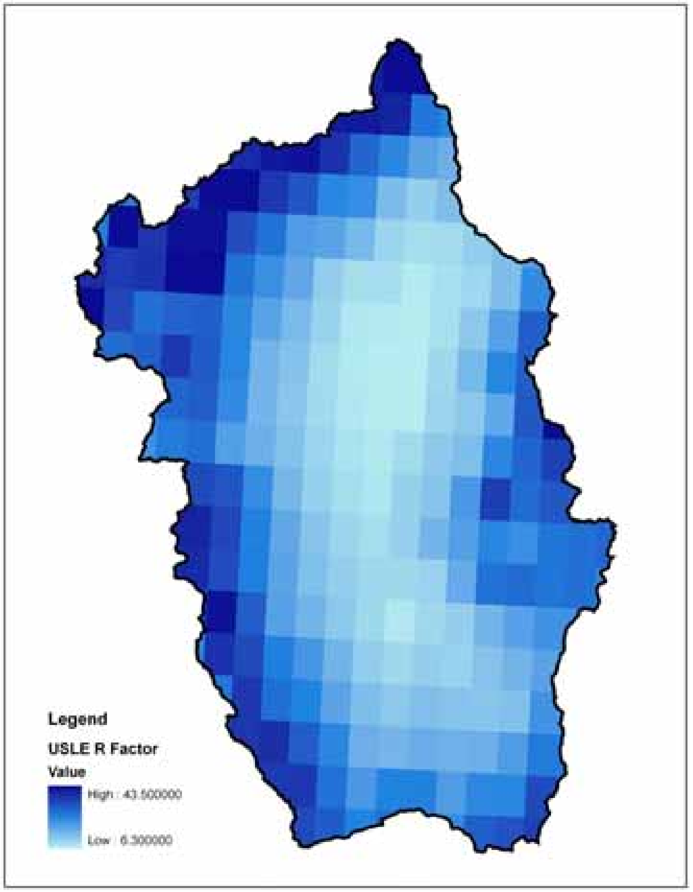



**Figure A-2. ULSE R factor for the upper Big Hole Watershed.**

<u>K-Factor</u>

The soil erodibility factor grid was compiled from 1:250K STATSGO data, as published by the NRCS. STATSGO database tables were queried to calculate a component weighted K value for all surface layers, which was then summarized by individual map unit. The map unit K values were then joined to a GIS polygon coverage of the STATSGO map units, and the polygon coverage was converted to a 10m analytic grid for use in this analysis.

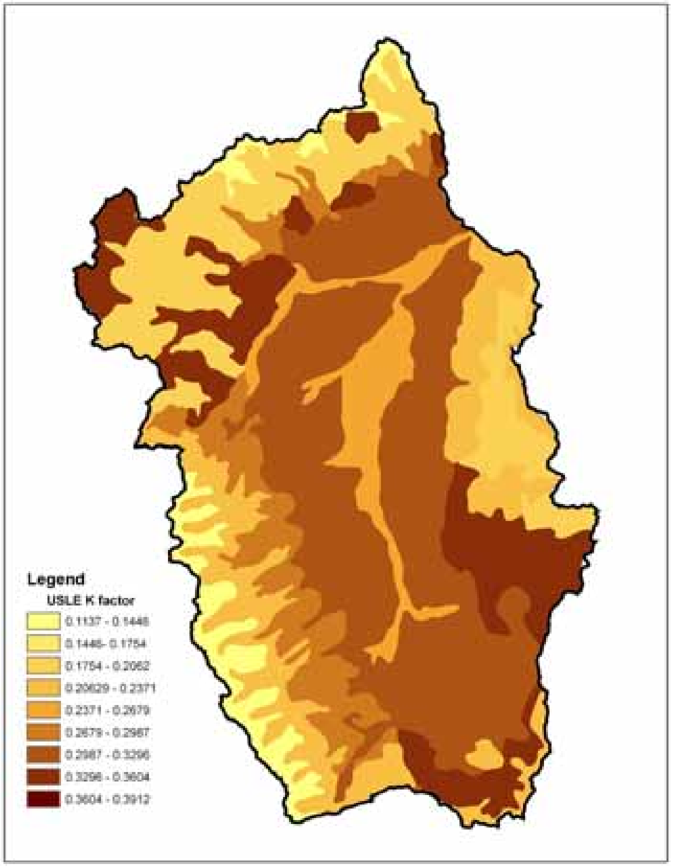



**Figure A-3. ULSE K factor for the Upper Big Hole Watershed.**

<u>LS- Factor</u>

The equation used for calculating the slope length and slope factor was that given in the updated definition of USLE, as published in USDA handbook #537:

$$LS = (\lambda/72.6)^m \, (65.41 \sin^2\theta + 4.56 \sin\theta + 0.065)$$

Where:

$\lambda$ = slope length in feet. This value was determined by applying GIS based surface analysis procedures to the upper Big Hole watershed DEM, calculating total upslope length for each 10m grid cell, and converting the results to feet from meters. In accordance with research that indicates that, in practice, the slope length rarely exceeds 400 ft, $\lambda$ was limited to that maximum value.

$\theta$ = cell slope as calculated by GIS based surface analysis procedures from the upper Big Hole watershed DEM

m = 0.5 if percent slope of the cell >= 5
= 0.4 if percent slope of the cell >= 3.5 AND < 5
= 0.3 if percent slope of the cell >= 1 AND < 3.5
= 0.2 if percent slope of the cell < 1

The LS factor grid was calculated from individual grids computed for each of these sub factors, using a simple ArcView Model Builder script.

C-Factor

The cover management factor of the USLE reflects the varying degree of erosion protection that results from different cover types. It integrates a number of factors including vegetative cover, plant litter, soil surface, and land management. For the purpose of this study, the C-factor is the only USLE parameter that can be altered by the influence of human activity. Based on this, C-factors were estimated for the existing condition and improved management scenarios (**Table A-2**). The C-factor change for agricultural cover types between management scenarios corresponds to increases in the percent of land cover that are achievable through the application of various best management practices (**Table A-3**). For natural sources (i.e. bare rock, deciduous forest, and evergreen forest), the C-factor is the same for both scenarios. A C-factor slightly higher than deciduous/evergreen forest was used for logged areas because logging intensity within the watershed is generally low and because practices, such as riparian clearcutting, that tend to produce high sediment yields have not been used since at least 1991, when the MT Streamside Management Zone (SMZ) law was enacted. Additionally, the USLE model is intended to reflect long-term average sediment yield, and while a sediment pulse typically occurs in the first year after logging, sediment production after the first year rapidly declines (Rice et al. 1972; Elliot and Robichaud 2001; Elliot 2006). The logging C-factor is the same for both management scenarios to indicate that logging will continue sporadically on public and private land within the watershed and will produce sediment at a rate slightly higher than an undisturbed forest. This is not intended to imply that additional best management practices beyond those in the SMZ law should not be used for logging activities. Because the Mussigbrod fire was in 2000 and the rate of erosion rapidly declines after the first year as vegetation re-establishes (Elliot and Robichaud 2001), the existing C-factor corresponds to the existing C-factor used in logged areas, and the improved C-factor varies depending on the improved C-factor for the underlying land cover type (see **Table A-2**).

C-factors were defined spatially through use of a modified version of the Anderson land cover classification (1976) and the 1992 30m Landsat Thematic Mapper (LTM) multi-spectral imaging (NLDC, 1992) (**Figure-4**). C-factor values were assigned globally to each land type and range from 0.001 to 1.0. These data were reprojected to Montana State plane projection/coordinate system, and resampled to the standard 10m grid. No field efforts were initiated as part of this study to refine C-factor estimation for the watershed.

**Table A-2. Upper Big Hole River C-Factor; Existing and improved management conditions.**

| NLCD Code | Description | C-Factor | |
|---|---|---|---|
| | | **Existing Condition** | **Improved Management Condition** |
| 31 | Bare Rock/Sand/Clay | 0.001 | 0.001 |
| 41 | Deciduous Forest | 0.003 | 0.003 |
| 42 | Evergreen Forest | 0.003 | 0.003 |
| 43 | Mixed Forest | 0.003 | 0.003 |
| 91 | Woody Wetlands | 0.0001 | 0.0001 |
| 51 | Shrubland | 0.046 | 0.031 |
| 71 | Grasslands Herbaceous | 0.042 | 0.035 |
| 81 | Pasture /Hay | 0.020 | 0.013 |
| 83 | Small Grains | 0.240 | 0.015 |
| N/A | Logging | 0.006 | 0.006 |
| N/A | Fire | 0.006 | Variable* |

*Improved C factor depends on the underlying land cover type

**Table A-3. Changes in percent ground cover for agricultural land cover types between existing and improved management conditions.**

| Land Cover | Existing % ground cover | Improved % ground cover |
|---|---|---|
| Shrubland | 55 | 65 |
| Grasslands Herbaceous | 55 | 65 |
| Pasture /Hay | 65 | 75 |
| Small Grains | 20 | 40 |

<u>NLCD – Landcover</u>

In general, the land use classification of the NLCD was accepted as is, without ground truthing of original results or correction of changes over the time since the NLCD image was taken. Given that we are looking for watershed and subwatershed scale effects, this was considered to be a reasonable assumption, given the relative simplicity of the land use mix in the Big Hole valley, and the relative stability of that land use over the 14 years since the Landsat image that the NLCD is based on was shot. Two adjustments were made to the NLCD, however. The first adjustment was to quantify the amount of logging that has occurred since 1992, and to also identify areas that are reforesting over that same period. The other adjustment was to account for change in land cover due to the Mussigbrod fire of 2000.

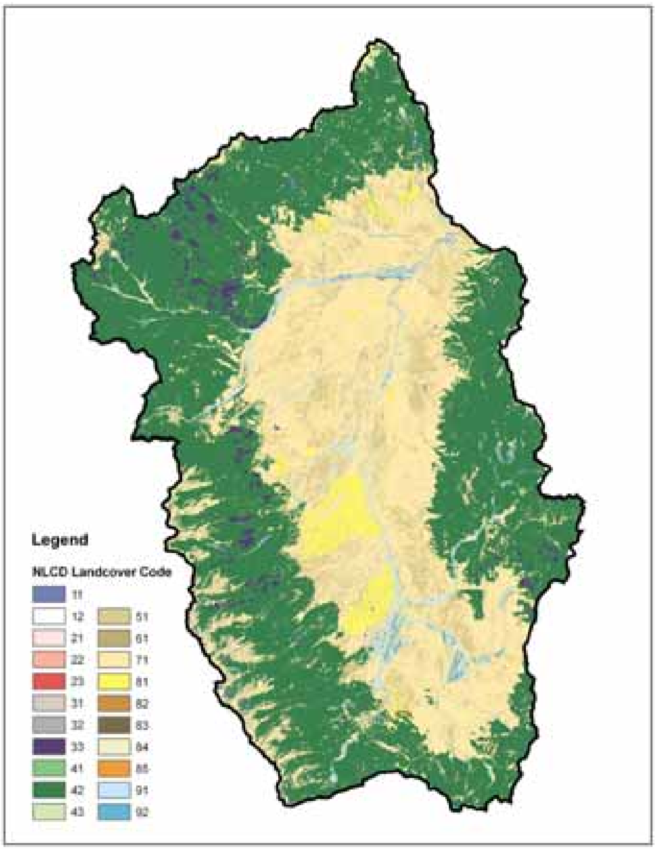



**Figure A-4. NLCD Landcover for the Upper Big Hole Watershed.**

As with other land uses in the valley, logging is a stable land use, but it is a land use that causes a land cover change that may effect sediment production. Similarly wildland fire, while not a landuse per se, is affected by land management decisions and may cause a change in vegetation cover. Adjustment for logging and reforestation was accomplished by comparing the 1992 NLCD grid for the upper Big Hole watershed with the 2005 NAIP aerial photography. Areas which were coded as a forest type (41 or 42) on the NLCD were recoded to 'logged' if:

- They appeared to be otherwise (typically bare ground, grassland, or shrubland) on the NAIP photos, and
- There were indications of indicated logging activity (proximity to forest or logging roads, appearance of stands, etc).

Adjustment for the land cover change caused by the Mussigbrod fire was accomplished by using the USFS mapping of the fire intensity within the burned area. Fire intensities of 'moderate mosaic' or above were considered to be land cover changing, and it was further assumed that these areas will eventually return (through natural processes or management activities) to their pre-fire condition.

<u>Sediment Delivery Ratio</u>
A sediment delivery ratio (SDR) factor was created for each grid cell, based on the relationship between the distance from the delivery point to the stream established by Dube, Megahan &

McCalmon in their development of the WARSEM road sediment model for the State of Washington. This relationship was developed by integrating the results of several previous studies, (principally those of Megehan and Ketchison), which examined sediment delivery to streams downslope of forest roads. They found that the proportion of sediment production that is ultimately delivered to streams declines with distance from the stream (**Table E-4**) with the balance of the sediment being deposited between the point of production and the stream. We believe the use of this relationship to develop a SDR for a USLE based model is a conservative (i.e. tending toward the high end of the range of reasonable values) estimate of sediment delivery from hillslope erosion, especially in light of the fact that the USLE methodology does not account for gully erosion. The SDR factor was applied to the results of the USLE model to estimate sediment delivered from hill slope sources, by calculating the distance from each cell to the nearest stream channel, and multiplying the sediment production of that cell by the corresponding distance based percentage of delivery.

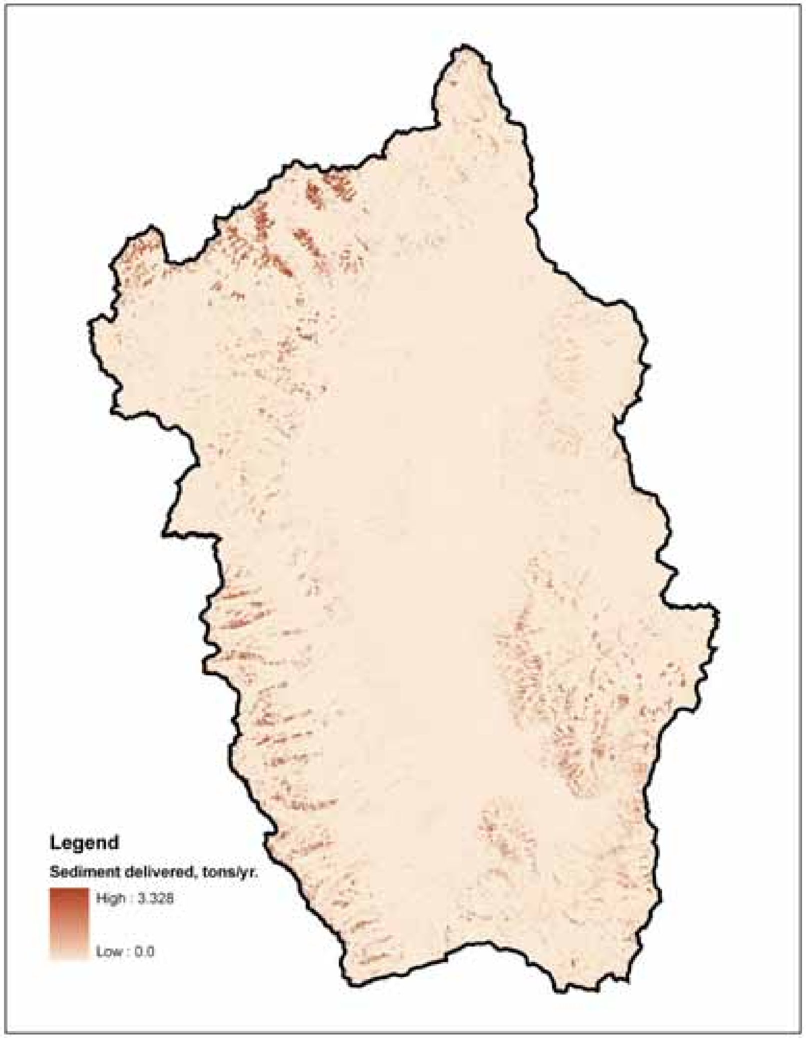
**Table A-4. The percent of sediment delivered by distance from a water body.**

| Distance from Culvert (ft) | Percent of Total Eroded Sediment Delivered |
|---|---|
| 0 | 100 |
| 35 | 70 |
| 70 | 50 |
| 105 | 35 |
| 140 | 25 |
| 175 | 18 |
| 210 | 10 |
| 245 | 4 |
| 280 | 3 |
| 315 | 2 |
| 350 | 1 |

Although the SDR factor accounts for the distance of sediment production cells from the stream channel, it does not account for riparian condition and the ability of riparian vegetation to filter out sediment and prevent it from entering the stream. Depending on the vegetation type and buffer width, healthy riparian buffers can remove anywhere from 50-90 percent of sediment (Castelle and Johnson 2000; Hook 2003; MDEQ 2007). Therefore, the USLE model used for source assessment may have overestimated existing loads and underestimated potential reductions due to hillslope erosion.

**Results**

**Figures A-5** and **A-6** present the USLE based hillslope model's prediction of existing and potential conditions for the upper Big Hole watershed. **Table A-5** contains the estimated existing and potential sediment load from hillslope erosion for each 6$^{th}$ code HUC and the upper Big Hole watershed, and it also contains loads normalized by the contributing watershed area. **Table A-6** contains the estimated existing and potential sediment load from hillslope erosion for the upper Big Hole watershed and broken out by 6$^{th}$ code HUC and existing land cover type.



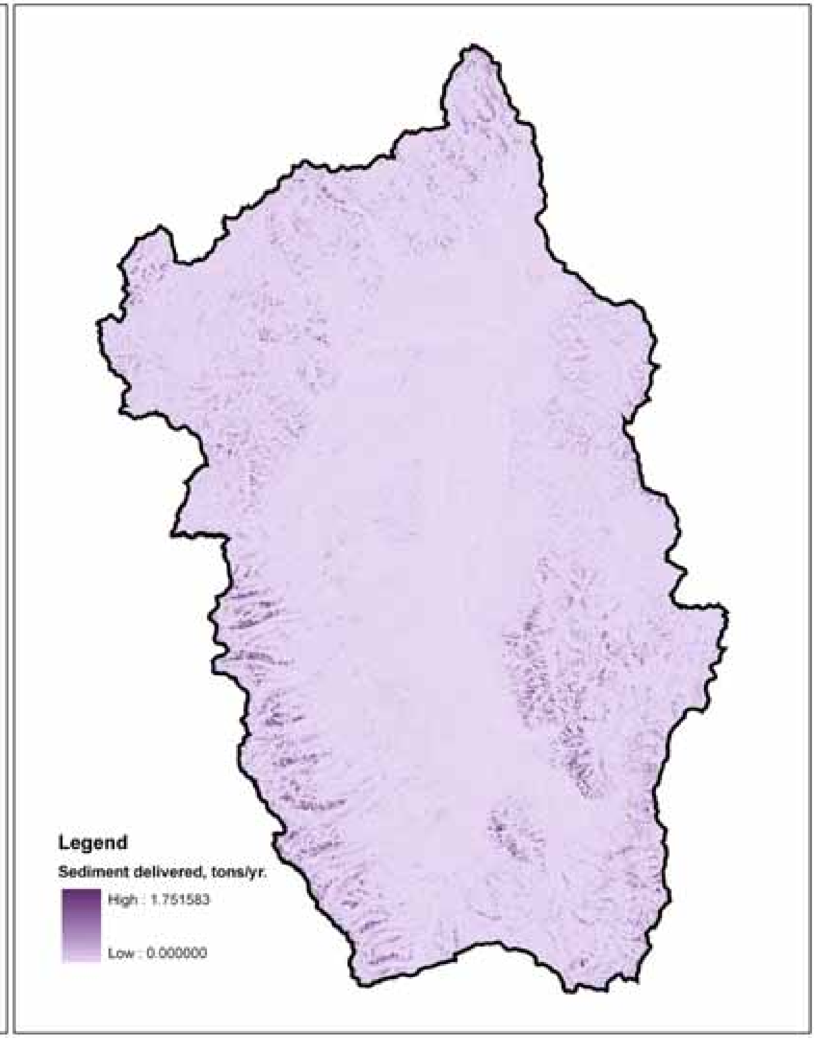




**Figure A-5. Estimated sediment delivery from hill slopes, existing conditions.**

**Figure A-6. Estimated sediment delivery from hill slopes, BMP conditions.**

**Table A-5. Total and normalized existing and potential sediment loads from upland erosion for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| 6th Code HUC Subwatershed | Acres | Existing Load (tons/yr) | Potential Load (tons/yr) | Normalized Existing Load (tons/acre/yr) | Normalized Potential Load (tons/acre/yr) |
|---|---|---|---|---|---|
| Andrus Creek | 12658 | 1250 | 1047 | 0.099 | 0.083 |
| Berry Creek | 9132 | 859 | 698 | 0.094 | 0.076 |
| Big Swamp Creek | 15256 | 1451 | 1170 | 0.095 | 0.077 |
| Big Hole River-Big Swamp Creek | 20532 | 524 | 423 | 0.026 | 0.021 |
| Big Hole River-McVey Homestead | 17216 | 184 | 146 | 0.011 | 0.009 |
| Big Hole River-Saginaw Creek | 14824 | 1085 | 756 | 0.073 | 0.051 |
| Big Hole River-Spring Creek | 20144 | 983 | 761 | 0.049 | 0.038 |
| Big Hole River-Squaw Creek | 8565 | 168 | 130 | 0.020 | 0.015 |
| Big Hole River-Wisdom | 17787 | 563 | 446 | 0.032 | 0.025 |
| Big Lake Creek | 28043 | 2246 | 1826 | 0.080 | 0.065 |
| Bull Creek | 30605 | 3067 | 2520 | 0.100 | 0.082 |
| Doolittle Creek | 13822 | 620 | 536 | 0.045 | 0.039 |
| Englejard Creek | 17476 | 1081 | 871 | 0.062 | 0.050 |
| Fox Creek | 7805 | 1062 | 870 | 0.136 | 0.111 |
| Francis Creek | 16143 | 584 | 502 | 0.036 | 0.031 |
| Headwaters Big Hole River | 20967 | 2237 | 1802 | 0.107 | 0.086 |
| Howell Creek | 12859 | 505 | 432 | 0.039 | 0.034 |
| Johnson Creek | 22269 | 1115 | 873 | 0.050 | 0.039 |
| Joseph Creek | 8004 | 322 | 301 | 0.040 | 0.038 |
| Little Lake Creek | 14775 | 1375 | 1108 | 0.093 | 0.075 |
| Lower Governor Creek | 17789 | 1166 | 911 | 0.066 | 0.051 |
| Lower Rock Creek | 10099 | 107 | 84 | 0.011 | 0.008 |
| Lower Trail Creek | 16558 | 729 | 655 | 0.044 | 0.040 |
| Lower Warm Springs Creek | 29047 | 2756 | 2248 | 0.095 | 0.077 |
| May Creek | 9839 | 414 | 387 | 0.042 | 0.039 |
| McVey Creek | 9426 | 369 | 310 | 0.039 | 0.033 |
| Miner Creek | 18088 | 2332 | 1892 | 0.129 | 0.105 |
| Mussigbrod Creek | 16207 | 1049 | 809 | 0.065 | 0.050 |
| North Fork Big Hole River | 26228 | 292 | 234 | 0.011 | 0.009 |
| Old Tim Creek | 14172 | 695 | 606 | 0.049 | 0.043 |
| Pine Creek | 3938 | 352 | 289 | 0.089 | 0.073 |
| Pintlar Creek | 17779 | 1513 | 1290 | 0.085 | 0.073 |
| Plimpton Creek | 28627 | 929 | 789 | 0.032 | 0.028 |
| Ruby Creek | 23915 | 1465 | 1272 | 0.061 | 0.053 |
| Schulz creek | 2383 | 80 | 54 | 0.034 | 0.023 |
| Stanley Creek | 11772 | 366 | 311 | 0.031 | 0.026 |
| Steel Creek | 17968 | 714 | 609 | 0.040 | 0.034 |
| Swamp Creek | 31427 | 1634 | 1312 | 0.052 | 0.042 |
| Tie Creek | 19561 | 854 | 759 | 0.044 | 0.039 |
| Upper Governor Creek | 10763 | 600 | 498 | 0.056 | 0.046 |
| Upper Rock Creek | 27615 | 1955 | 1606 | 0.071 | 0.058 |
| Upper Trail Creek | 16149 | 805 | 644 | 0.050 | 0.040 |
| Upper Warm Springs Creek | 12404 | 386 | 331 | 0.031 | 0.027 |

**Table A-5. Total and normalized existing and potential sediment loads from upland erosion for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| 6th Code HUC Subwatershed | Acres | Existing Load (tons/yr) | Potential Load (tons/yr) | Normalized Existing Load (tons/acre/yr) | Normalized Potential Load (tons/acre/yr) |
|---|---|---|---|---|---|
| West Fork Ruby Creek | 10202 | 570 | 499 | 0.056 | 0.049 |
| **Upper Big Hole Watershed** | **730837** | **43414** | **35618** | **0.059** | **0.049** |

**Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| Subwatershed | Land Cover Classification | Existing Sediment (tons/yr) | Potential Sediment (tons/yr) |
|---|---|---|---|
| Andrus Creek | Evergreen Forest | 292 | 292 |
| | Grasslands/Herbaceous | 684 | 570 |
| | Shrubland | 274 | 185 |
| Andrus Creek Total | | 1250 | 1047 |
| Berry Creek | Bare Rock/Sand/Clay | 5 | 5 |
| | Evergreen Forest | 153 | 153 |
| | Grasslands/Herbaceous | 425 | 354 |
| | Shrubland | 275 | 186 |
| Berry Creek Total | | 859 | 698 |
| Big Swamp Creek | Bare Rock/Sand/Clay | 9 | 9 |
| | Evergreen Forest | 216 | 216 |
| | Grasslands/Herbaceous | 654 | 545 |
| | Pasture/Hay | 1 | <1 |
| | Shrubland | 525 | 354 |
| | Logging | 46 | 46 |
| Big Swamp Creek Total | | 1451 | 1170 |
| Big Hole River-Big Swamp Creek | Evergreen Forest | 77 | 77 |
| | Grasslands/Herbaceous | 286 | 239 |
| | Pasture/Hay | 21 | 14 |
| | Shrubland | 139 | 94 |
| Big Hole River-Big Swamp Creek Total | | 524 | 423 |
| Big Hole River-McVey Homestead | Evergreen Forest | 2 | 2 |
| | Grasslands/Herbaceous | 143 | 119 |
| | Pasture/Hay | 1 | <1 |
| | Shrubland | 38 | 26 |
| Big Hole River-McVey Homestead Total | | 184 | 146 |
| Big Hole River-Saginaw Creek | Evergreen Forest | 114 | 114 |
| | Grasslands/Herbaceous | 521 | 434 |
| | Logging | 6 | 6 |
| | Pasture/Hay | 13 | 8 |
| | Shrubland | 273 | 184 |
| | Small Grains | 160 | 10 |
| Big Hole River-Saginaw Creek Total | | 1085 | 756 |

**Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| Subwatershed | Land Cover Classification | Existing Sediment (tons/yr) | Potential Sediment (tons/yr) |
|---|---|---|---|
| Big Hole River-Spring Creek | Evergreen Forest | 23 | 23 |
| | Grasslands/Herbaceous | 554 | 461 |
| | Logging | 8 | 8 |
| | Pasture/Hay | 14 | 9 |
| | Shrubland | 383 | 258 |
| | Woody Wetlands | 1 | 1 |
| Big Hole River-Spring Creek Total | | 983 | 761 |
| Big Hole River-Squaw Creek | Evergreen Forest | 4 | 4 |
| | Grasslands/Herbaceous | 99 | 83 |
| | Shrubland | 65 | 44 |
| Big Hole River-Squaw Creek Total | | 168 | 130 |
| Big Hole River-Wisdom | Evergreen Forest | 27 | 27 |
| | Grasslands/Herbaceous | 361 | 301 |
| | Shrubland | 176 | 118 |
| Big Hole River-Wisdom Total | | 563 | 446 |
| Big Lake Creek | Bare Rock/Sand/Clay | 5 | 5 |
| | Evergreen Forest | 351 | 351 |
| | Grasslands/Herbaceous | 1194 | 995 |
| | Pasture/Hay | 17 | 11 |
| | Shrubland | 661 | 445 |
| | Logging | 18 | 18 |
| Big Lake Creek Total | | 2246 | 1826 |
| Bull Creek | Emergent Herbaceous Wetlands | 2 | 2 |
| | Evergreen Forest | 202 | 202 |
| | Grasslands/Herbaceous | 2293 | 1908 |
| | Logging | 70 | 70 |
| | Shrubland | 499 | 336 |
| | Woody Wetlands | 1 | 1 |
| Bull Creek Total | | 3067 | 2520 |
| Doolittle Creek | Evergreen Forest | 246 | 246 |
| | Grasslands/Herbaceous | 239 | 199 |
| | Shrubland | 134 | 91 |
| Doolittle Creek Total | | 620 | 536 |
| Englejard Creek | Bare Rock/Sand/Clay | 4 | 4 |
| | Evergreen Forest | 153 | 153 |
| | Grasslands/Herbaceous | 581 | 484 |
| | Pasture/Hay | 2 | <1 |
| | Shrubland | 342 | 230 |
| Englejard Creek Total | | 1081 | 871 |

**Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| Subwatershed | Land Cover Classification | Existing Sediment (tons/yr) | Potential Sediment (tons/yr) |
|---|---|---|---|
| Fox Creek | Evergreen Forest | 190 | 190 |
| | Grasslands/Herbaceous | 574 | 478 |
| | Shrubland | 296 | 200 |
| | Woody Wetlands | 1 | 1 |
| Fox Creek Total | | 1062 | 870 |
| Francis Creek | Evergreen Forest | 186 | 186 |
| | Grasslands/Herbaceous | 291 | 242 |
| | Logging | 6 | 6 |
| | Shrubland | 100 | 67 |
| Francis Creek Total | | 584 | 502 |
| Headwaters Big Hole River | Bare Rock/Sand/Clay | 4 | 4 |
| | Evergreen Forest | 439 | 439 |
| | Grasslands/Herbaceous | 945 | 787 |
| | Shrubland | 849 | 572 |
| Headwaters Big Hole River Total | | 2237 | 1802 |
| Howell Creek | Evergreen Forest | 219 | 219 |
| | Grasslands/Herbaceous | 133 | 111 |
| | Pasture/Hay | 2 | 1 |
| | Shrubland | 149 | 100 |
| | Small Grains | 2 | <1 |
| Howell Creek Total | | 505 | 432 |
| Johnson Creek | Evergreen Forest | 343 | 343 |
| | Fire | 318 | 168 |
| | Grasslands/Herbaceous | 266 | 220 |
| | Logging | 50 | 50 |
| | Shrubland | 138 | 93 |
| Johnson Creek Total | | 1115 | 873 |
| Joseph Creek | Evergreen Forest | 230 | 230 |
| | Grasslands/Herbaceous | 35 | 29 |
| | Shrubland | 47 | 32 |
| | Logging | 6 | 6 |
| | Woody Wetlands | 4 | 4 |
| Joseph Creek Total | | 322 | 301 |
| Little Lake Creek | Bare Rock/Sand/Clay | 10 | 10 |
| | Evergreen Forest | 179 | 179 |
| | Grasslands/Herbaceous | 748 | 623 |
| | Shrubland | 438 | 295 |
| Little Lake Creek Total | | 1375 | 1108 |

**Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| Subwatershed | Land Cover Classification | Existing Sediment (tons/yr) | Potential Sediment (tons/yr) |
|---|---|---|---|
| Lower Governor Creek | Emergent Herbaceous Wetlands | 1 | 1 |
| | Grasslands/Herbaceous | 779 | 649 |
| | Shrubland | 385 | 260 |
| | Woody Wetlands | 1 | 1 |
| Lower Governor Creek Total | | 1166 | 911 |
| Lower Rock Creek | Grasslands/Herbaceous | 77 | 64 |
| | Shrubland | 29 | 20 |
| Lower Rock Creek Total | | 107 | 84 |
| Lower Trail Creek | Evergreen Forest | 398 | 398 |
| | Grasslands/Herbaceous | 95 | 79 |
| | Logging | 55 | 55 |
| | Shrubland | 179 | 121 |
| | Woody Wetlands | 2 | 2 |
| Lower Trail Creek Total | | 729 | 655 |
| Lower Warm Springs Creek | Deciduous Forest | 1 | 1 |
| | Emergent Herbaceous Wetlands | 2 | 2 |
| | Evergreen Forest | 488 | 488 |
| | Grasslands/Herbaceous | 1398 | 1164 |
| | Logging | 14 | 14 |
| | Shrubland | 844 | 569 |
| | Woody Wetlands | 10 | 10 |
| Lower Warm Springs Creek Total | | 2756 | 2248 |
| May Creek | Evergreen Forest | 308 | 308 |
| | Grasslands/Herbaceous | 47 | 39 |
| | Shrubland | 60 | 40 |
| May Creek Total | | 414 | 387 |
| McVey Creek | Evergreen Forest | 100 | 100 |
| | Grasslands/Herbaceous | 180 | 150 |
| | Shrubland | 89 | 60 |
| McVey Creek Total | | 369 | 310 |
| Miner Creek | Bare Rock/Sand/Clay | 13 | 13 |
| | Evergreen Forest | 257 | 257 |
| | Grasslands/Herbaceous | 1460 | 1217 |
| | Pasture/Hay | 2 | 1 |
| | Shrubland | 600 | 404 |
| Miner Creek Total | | 2332 | 1892 |
| Mussigbrod Creek | Evergreen Forest | 303 | 303 |
| | Fire | 317 | 168 |
| | Grasslands/Herbaceous | 297 | 247 |
| | Logging | 5 | 5 |
| | Shrubland | 127 | 85 |
| Mussigbrod Creek Total | | 1049 | 809 |

**Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| Subwatershed | Land Cover Classification | Existing Sediment (tons/yr) | Potential Sediment (tons/yr) |
|---|---|---|---|
| North Fork Bighole River | Evergreen Forest | 26 | 26 |
| | Grasslands/Herbaceous | 193 | 161 |
| | Logging | 6 | 6 |
| | Pasture/Hay | 5 | 3 |
| | Shrubland | 58 | 39 |
| | Small Grains | 4 | <1 |
| North Fork Bighole River Total | | 292 | 234 |
| Old Tim Creek | Evergreen Forest | 336 | 336 |
| | Grasslands/Herbaceous | 151 | 126 |
| | Shrubland | 194 | 131 |
| | Logging | 13 | 13 |
| Old Tim Creek Total | | 695 | 606 |
| Pine Creek | Evergreen Forest | 141 | 141 |
| | Grasslands/Herbaceous | 33 | 28 |
| | Shrubland | 178 | 120 |
| Pine Creek Total | | 352 | 289 |
| Pintlar Creek | Evergreen Forest | 520 | 520 |
| | Fire | 10 | 5 |
| | Grasslands/Herbaceous | 638 | 532 |
| | Logging | 1 | 1 |
| | Shrubland | 344 | 232 |
| Pintlar Creek Total | | 1513 | 1290 |
| Plimpton Creek | Evergreen Forest | 290 | 290 |
| | Fire | 2 | <1 |
| | Grasslands/Herbaceous | 452 | 377 |
| | Logging | 1 | 1 |
| | Pasture/Hay | 3 | 2 |
| | Shrubland | 177 | 120 |
| | Small Grains | 4 | <1 |
| Plimpton Creek Total | | 929 | 789 |
| Ruby Creek | Evergreen Forest | 571 | 571 |
| | Grasslands/Herbaceous | 573 | 477 |
| | Logging | 21 | 21 |
| | Shrubland | 296 | 199 |
| | Woody Wetlands | 4 | 4 |
| Ruby Creek Total | | 1465 | 1272 |
| Schulz creek | Evergreen Forest | 6 | 6 |
| | Fire | 56 | 30 |
| | Shrubland | 1 | 1 |
| | Logging | 18 | 18 |
| Schulz creek Total | | 80 | 54 |

**Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| **Subwatershed** | **Land Cover Classification** | **Existing Sediment (tons/yr)** | **Potential Sediment (tons/yr)** |
|---|---|---|---|
| Stanley Creek | Evergreen Forest | 91 | 91 |
| | Grasslands/Herbaceous | 223 | 186 |
| | Logging | 1 | 1 |
| | Pasture/Hay | 1 | <1 |
| | Shrubland | 50 | 34 |
| Stanley Creek Total | | 366 | 311 |
| Steel Creek | Evergreen Forest | 275 | 275 |
| | Grasslands/Herbaceous | 237 | 197 |
| | Logging | 1 | 1 |
| | Shrubland | 201 | 136 |
| Steel Creek Total | | 714 | 609 |
| Swamp Creek | Bare Rock/Sand/Clay | 3 | 3 |
| | Evergreen Forest | 201 | 201 |
| | Grasslands/Herbaceous | 893 | 744 |
| | Logging | 6 | 6 |
| | Shrubland | 531 | 358 |
| Swamp Creek Total | | 1634 | 1312 |
| Tie Creek | Evergreen Forest | 436 | 436 |
| | Fire | 28 | 15 |
| | Grasslands/Herbaceous | 126 | 104 |
| | Logging | 79 | 79 |
| | Shrubland | 186 | 125 |
| Tie Creek Total | | 854 | 759 |
| Upper Governor Creek | Evergreen Forest | 63 | 63 |
| | Grasslands/Herbaceous | 458 | 382 |
| | Logging | 2 | 2 |
| | Shrubland | 75 | 51 |
| Upper Governor Creek Total | | 600 | 498 |
| Upper Rock Creek | Bare Rock/Sand/Clay | 3 | 3 |
| | Evergreen Forest | 190 | 190 |
| | Grasslands/Herbaceous | 1373 | 1144 |
| | Logging | 21 | 21 |
| | Pasture/Hay | 11 | 7 |
| | Shrubland | 359 | 242 |
| Upper Rock Creek Total | | 1955 | 1606 |

**Table A-6. Existing and potential sediment loads from upland erosion by land cover type for each 6th code HUC (Sub-Watershed) and for the upper Big Hole watershed (i.e. all HUCs).** The upper Big Hole watershed is bolded.

| **Subwatershed** | **Land Cover Classification** | **Existing Sediment (tons/yr)** | **Potential Sediment (tons/yr)** |
|---|---|---|---|
| Upper Trail Creek | Deciduous Forest | 1 | 1 |
| | Evergreen Forest | 247 | 247 |
| | Fire | 121 | 65 |
| | Grasslands/Herbaceous | 229 | 190 |
| | Shrubland | 201 | 135 |
| | Logging | 4 | 4 |
| | Woody Wetlands | 2 | 2 |
| Upper Trail Creek Total | | 805 | 644 |
| Upper Warm Springs Creek | Evergreen Forest | 154 | 154 |
| | Grasslands/Herbaceous | 132 | 110 |
| | Shrubland | 100 | 67 |
| Upper Warm Springs Creek Total | | 386 | 331 |
| West Fork Ruby Creek | Evergreen Forest | 269 | 269 |
| | Grasslands/Herbaceous | 169 | 140 |
| | Shrubland | 132 | 89 |
| West Fork Ruby Creek Total | | 570 | 499 |
| **Upper Big Hole Watershed** | **Bare Rock/Sand/Clay** | **56** | **56** |
| | **Deciduous Forest** | **2** | **2** |
| | **Emergent Herbaceous Wetlands** | **5** | **5** |
| | **Evergreen Forest** | **9315** | **9315** |
| | **Fire** | **851** | **450** |
| | **Grasslands/Herbaceous** | **21238** | **17691** |
| | **Logging** | **459** | **459** |
| | **Pasture/Hay** | **93** | **57** |
| | **Shrubland** | **11198** | **7546** |
| | **Small Grains** | **170** | **10** |
| | **Woody Wetlands** | **27** | **27** |
| **Upper Big Hole Watershed Total** | | **43414** | **35618** |

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